TD E070.0490

PORTABLE NEUTRON COUNTER
MODEL PNR-4

DOCUMENT NUMBER TD E070.0490

RECORD OF REVISIONS

TITLE OF DOCUMENT

PORTABLE NEUTRON COUNTER
MODEL PNR-4

REVISION NUMBER	DATE	DESCRIPTION OF REVISION	REVISED BY
0	06/02/88	ORIGINAL	

TD E070.0490

Model PNR-4

LIN-LOG
Portable Neutron
Rem Counter
Technical Manual

Eberline A subsidiary of
Thermo Instrument
Systems Inc.

Service Centers

CERTIFIED CALIBRATION REPAIR

Eberline Instruments, Certified Calibration ("non-removable" contaminated instruments also calibrated)	Call Service center for prices
Other Manufacturer's Instruments, Certified Calibration	$115.00 each
Repair Rate above Calibration plus Parts at List Price	$ 70.00/hour
Repair Rate above Calibration plus Parts at List Price for "non-removable" contaminated instruments	$ 87.50/hour

Contractual rates are available for periodic repair and/or calibration. Contact Service Centers for prices.

Technical Specification Writing and Consultation	Call Service Center for prices
Service Engineer at Customer's site	$730/day plus expenses at cost

MISCELLANEOUS

1. Turn Around Time:

   Calibration: Seven (7) working days on Eberline Instruments.
   Repair: Fifteen (15) working days on Eberline instruments unless parts have to be ordered.

2. FOB Santa Fe, New Mexico, or West Columbia, South Carolina.

3. Instruments for warranty repair, repair, or calibration must be sent to:

   Instrument Repair and Calibration
   Eberline Instrument Corporation
   P.O. Box 2108, 504 Airport Road
   Santa Fe, New Mexico 87504-2108
   Telephone: (505)471-3232
   1-800-274-4212

   Instrument Repair and Calibration
   Eberline Instrument Corporation
   312 Miami Street
   West Columbia, South Carolina 29169
   Telephone: (803)796-3604
   1-800-234-4212

4. In addition, the following Customer Service Center is available for customers outside the United States:

   Thermo Electron, Ltd.
   Woolborough Lane
   Crawley, West Sussex
   England, RH10 2AQ

Prices at this location will vary from U.S. prices. Please contact the facility for current price and delivery information.

December 1987

Repair and Calibration Warranty

Eberline warrants to replace or repair, at its option, any repaired products or replaced parts thereof (excluding tubes, crystals, batteries and normal consumables) which are found defective in material or workmanship within ninety (90) days from date of repair or the balance of the new purchase warranty, whichever occurs later. Instruments calibrated by Eberline are warranted to be within specified limits at time of shipment. In the event of calibration error, Eberline will again calibrate the instrument without charge to the instrument owner. The aforesaid warranty does not cover life-end failure of components and will be voided if repair has been attempted by other than seller's authorized personnel. In no event shall Eberline be liable for consequential or special damages, transportation, installation, adjustment, work done by customer or other expenses which may arise in connection with such defective product or parts.

Exclusion of Warranties and Limitation of Liability

The foregoing warranty is expressly made in lieu of any and all other warranties expressed or implied, including the warranties of merchantability and fitness of a particular purpose. Under no circumstances shall seller be liable for any indirect, special, incidental, or consequential damages to customer or to any third party.

December 1987

Eberline *A subsidiary of* ***Thermo Instrument*** *Systems Inc.*

P.O. Box 2108
Santa Fe, New Mexico 87504-2108
(505) 471-3232 TWX: 910-985-0678

LIST OF EFFECTIVE PAGES

THE TOTAL NUMBER OF PAGES IN THIS MANUAL IS 22 CONSISTING OF THE FOLLOWING:

Page No	Change In Effect	Latest Publication Date
Title	Change 1	March 1, 1983
A	Change 11	March 14, 1986
i	Change 6	June 20, 1988
ii	Change 1	September 4, 1978
1	Change 4	March 1, 1983
2	Change 5	June 20, 1988
3	Change 5	March 1, 1983
5	Change 3	June 20, 1988
6	Change 2	March 1, 1983
7	Change 2	March 1, 1983
8	Change 5	June 20, 1988
9	Change 3	June 20, 1988
10	Change 2	March 1, 1983
11	Change 4	June 20, 1988
12	Change 1	June 20, 1988
13	Change 5	June 20, 1988
15	Change 1	June 20, 1988
16	Change 1	June 20, 1988
17	Change 1	June 20, 1988
18	Change 1	June 20, 1988

Pages 4 and 14 are blank.

Pages not noted above are original issue dated March 1, 1983

Copyright © 1968 by Eberline Instrument Corporation

TABLE OF CONTENTS

Section Page

I GENERAL

Purpose and Description 1
Specifications 1

II OPERATION

Description of Controls and Connectors 5
Preparation for Use 5
Using the Instrument 5

III THEORY OF OPERATION

General 7
Functional Theory 7

IV MAINTENANCE

Disassembly and Reassembly 9
Preventive Maintenance 9
Calibration 9
Troubleshooting 10

V PARTS LIST 11

VI DIAGRAMS 15

VII P-201B HIGH VOLTAGE POWER SUPPLY 17

LIST OF ILLUSTRATIONS

Figure Page

1-1 Model PNR-4, Portable Neutron rem Counter ii
1-2 Typical Temperature Coefficient for High Voltage 2
1-3 Typical Meter Error vs Temperature 2
2-1 Neutron Energy Response Curve 5
2-2 Model PNR-4 Exterior Controls 6
2-3 Model PNR-4 Interior Controls 6
3-1 System Block Diagram 8
4-1 Typical High Voltage Plateau Curve for PNR-4 Detector 10
6-1 General Schematic of Model PNR-4 15
6-2 Component Layout of Driver Card P-203-4 16
6-3 Component Layout of Amp-Discr-Binary Card P-202 16
6-4 Component Layout of High Voltage Supply Card P-201A-1000 16
6-5 P-201B Schematic 19
6-6 P-201B Component Assembly 20

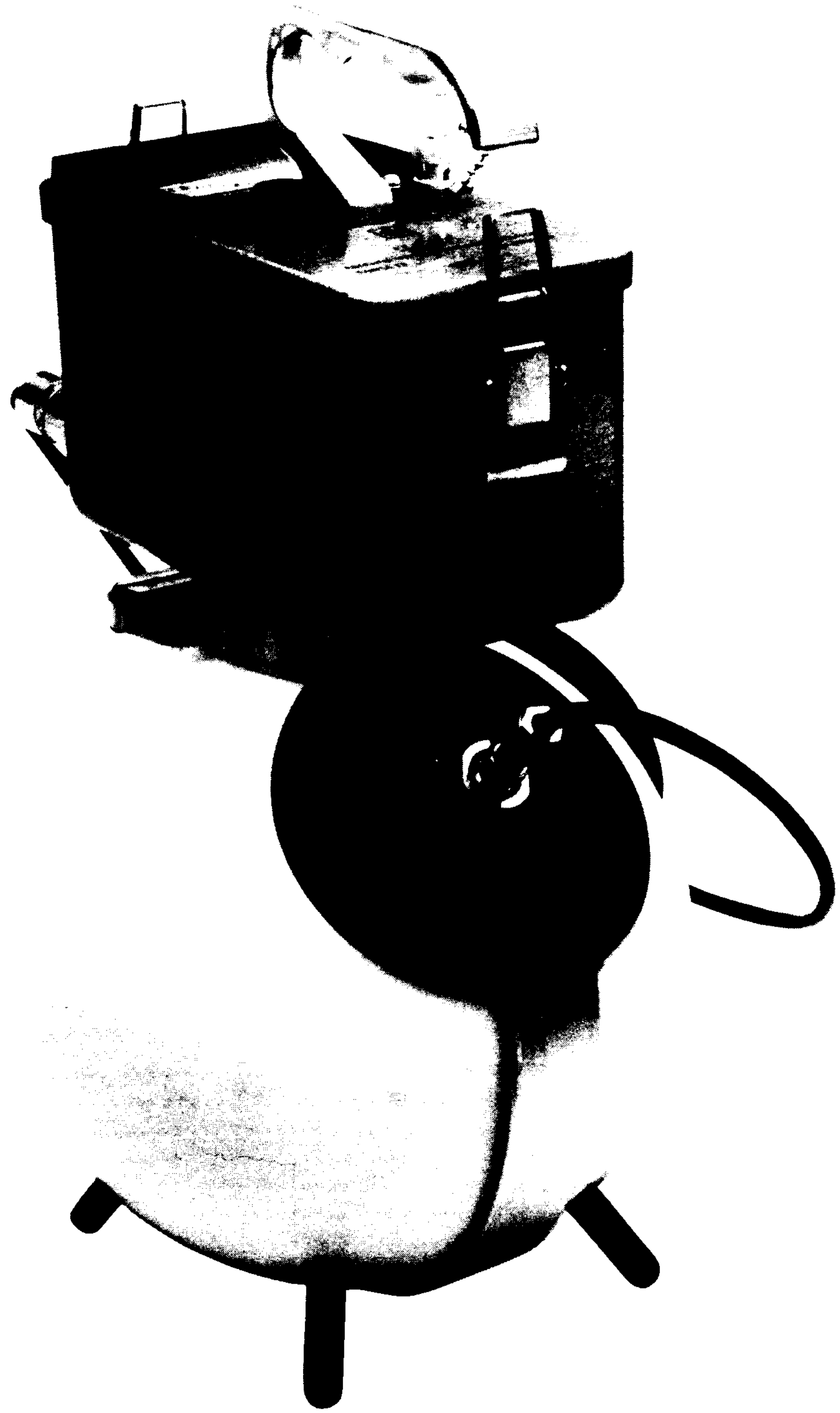


Figure 1-1. Model PNR-4, Portable Neutron rem Counter

SECTION I
GENERAL

A. PURPOSE AND DESCRIPTION

The PNR-4 is a portable, battery-operated instrument for the detection and measurement of the dose rate from neutron radiation. The instrument detector is a 9-inch-diameter cadmium-loaded, polyethylene sphere with a BF_3 tube in the center. This detector has been shown to have a response which closely follows the theoretical dose from neutrons over the energy range from 0.025 eV (thermal) to about 10 MeV.[1,2] The BF_3 tube allows excellent gamma rejection.

The dose rate is read out by the Eberline LIN-LOG presentation, which eliminates scale switching and multiplying factors, yet retains linear increments within each decade. Four decades are covered using two meter movements to yield a scale length of about 1.5 inches per decade, which gives maximum readability and ease of interpretation. Full-scale readings of the four decades are 5, 50, 500 and 5,000 mrem per hour respectively.

The counter may be detached from the detector for remote monitoring or ease of carrying. The counter electronics are mounted on three plug-in etched circuit boards for ease of maintenance.

The battery pack uses five standard "D" cells of any type commercially available (C-Zn, mercury, Ni-Cd, alkaline). This allows choice of types depending on what feature is considered most important. A battery condition check is provided on the front panel.

Aural monitoring capability is included by means of a connector on the front panel. Either a headset or an Eberline Model SK-1 speaker may be used.

B. SPECIFICATIONS

1. Detector

a. BF_3 Tube: ½-inch-diameter x 1-inch-long (1.3 cm x 2.5 cm) sensitive volume, 60 cm Hg fill pressure.

b. Plateau: Approximately 200 V with slope of 5 percent per 100 V.

c. Operating Voltage: Nominal + 1800 V; however, the optimium voltage depends on cable length, input sensitivity of counter, and degree of gamma rejection required.

d. Sensitivity: Approximately 50 cpm (counts per minute) per mrem per hour (3000 counts per mrem).

e. Energy Response: See Figure 2-1 and footnotes 1 and 2.

f. Directionality: ±10 percent.

g. Gamma Rejection: Up to 500 R/h, dependent on high voltage setting. Normal factory calibration provides 10 R/h rejection of ^{137}Cs gamma.

h. Connector: MHV series coaxial.

2. Indicators

a. Visual

(1) Scale Marking: 10 divisions per decade with numbers at one-half and full decades.

(2) Scale Length: Nominal 6.32 inches (16 cm), (1.74 inches [4.4 cm] first and third decades, 1.42 inches [3.6 cm] second and fourth decades).

(3) Response Time: Different for each decade and varies somewhat with calibration setting. Nominal 12 seconds first decade, 6 seconds second decade, 1.5 seconds third decade, 0.3 seconds fourth decade.

(4) Linearity: ±8 percent of full scale of the decade in which it is reading when properly calibrated and driven with a repetitive signal.

b. Aural

(1) Connector; BNC series coaxial.

(2) Signal: Direct coupled square wave, 5 V through 22 kΩ. Each event counted changes state of output.

---

[1] "A Modified-Sphere Neutron Detector", D.E. Hankins, LA-3395.

[2] "The Substitution of a BF_3 Tube for the LiI Crystal in Neutron rem Meters", D.E. Hankins, *Health Physics Journal,* Volume 14, No. 5, May 1968.

3. Power

a. Instrument Requirements

(1) Voltage 6.0 minimum to 8 maximum Vdc.

(2) Current depends on battery voltage and high voltage supply setting. Nominal 20 mA at 6.0 V, and 30 mA at 8 V.

b. Battery Pack

(1) Standard equipment is the Eberline Model BP-1-3 with five alkaline "D" cells. The BP-1-3 will accept any "D" cell batteries. Minimum voltage is 1.2 V per cell. Maximum voltage is 1.6 V per cell.

c. Battery Life

(1) Highly variable depending on current drain (3.a.2. above), battery type, age, and temperature. Nominal life with new batteries as listed below.

C-Zn (not recommended)	200 hours
Alkaline	330 hours
Ni-Cd (single charge)	160 hours*
Mercury	560 hours

*For this operating life, the Ni-Cd batteries must be allowed to discharge past the 6.0 V cutoff point. A test should be run to ensure that the high voltage remains on the detector plateau under these conditions.

4. Electronics

a. High Voltage Output: Adjustable from less than +300 V to at least +2500 V.

b. High Voltage Regulation: Less than ±25 V change with battery change from 8 to 6.0 V referred to 7.0 V.

c. High Voltage Output Impedance: Approximately 6 MΩ.

d. Counter Input Sensitivity: Variable from 1 mV to 50 mV by card-mounted adjustment.

e. Counter Input Impedance: Approximately 40 kΩ.

f. Calibration: Four chassis-mounted adjustments. Typical calibration range from one-half to two times nominal calibration point.

5. Environmental

a. Mechanical: Die-cast cover and chassis, drawn aluminum case, and securely clamped components for extreme ruggedness.

b. Sealing: Splashproof by use of O-rings at all external components and mating surfaces.

c. Temperature: The electronics of the instrument is operational from -40 °F to + 140 °F (-40 °C to 60 °C). Resetting of the high voltage adjustment (*H.V. ADJUST)* control may be necessary at the temperature extremes because of either: (1) plateau shift of the detector, (2) sensitivity shift of the electronics or, (3) shift of the high voltage output itself (see Figure 1-2). If properly set up, the meter reading over the entire temperature span is typically within ±10 percent of full scale of the decade within which it is reading (see Figure 1-3).

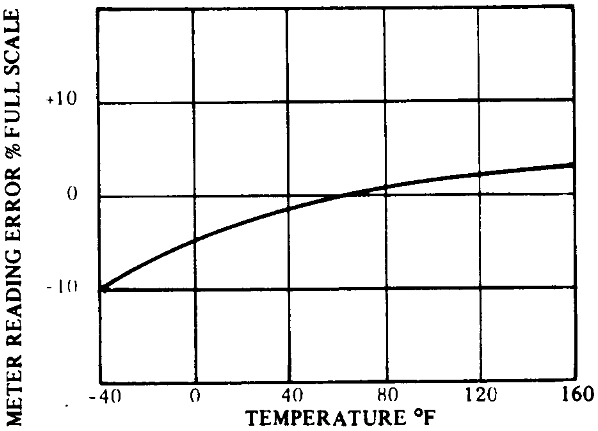


Figure 1-3. Typical Meter Error vs Temperature

The battery type used limits the low temperature performance of the instrument because of terminal voltage decrease and internal impedance increase. Any battery type will give one to four hours of service when taken from room temperature to -40 °F because of the insulation provided. For longer periods the following criteria are suggested:

Type	**Temperature**
Mercury	+30 °F (- 1 °C)
C-Zn	0 °F (-18 °C)
Alkaline	-40 °F (-40 °C)
Ni-Cd	-40 °F (-40 °C)

6. Mechanical

a. Size

Detector: 9-inch-diameter (22.9 cm), 9 7/8-inch overall height (25.1 cm).

Counter: 9 1/2 inches long (24.1 cm) (less cable) x 4 inches wide (10.2 cm) x 7 1/4 inches high (18.4 cm).

b. Weight

Detector and cable: 13 3/4 pounds (6.24 kg).

Counter (with C-Zn batteries): 5 3/4 pounds (2.61 kg).

Total weight is 19 1/2 pounds (8.85 kg).

SECTION II
OPERATION

A. DESCRIPTION OF CONTROLS AND CONNECTORS

1. External (See Figure 2-2)

a. Switch: A three-position switch turns the instrument *OFF, ON* or performs a battery *(BATT)* check. Spring return from *BATT* check position.

b. *H.V. ADJUST:* Controls the magnitude of high voltage applied to the detector. Clockwise rotation increases the voltage. There are radial marks around the control for reference.

c. *PHONE:* For connection of headset, speaker or external scaler. Mating connector is UG-88/U (BNC).

d. Detector Connector: For connection to the detector. Mating connector is Eberline Model CP-1.

2. Internal (See Figure 2-3)

a. Calibration Controls: Four controls to adjust the meter reading to agree with neutron dose rate at the detector.

b. Sensitivity Control: A multi-turn control mounted on the P-202 card adjusts the input sensitivity.

B. PREPARATION FOR USE

1. Inspection

The instrument should be checked for physical damage.

2. Connections

Connect the cable to the instrument and the detector to the cable.

NOTE

Hand tighten only. DO NOT use tools.

C. USING THE INSTRUMENT

1. Starting

Turn the switch to the *BATT* check position. The left pointer (black) should read in the "BATT" area. Release the switch and it will return to the *ON* position.

2. Interpretation of Indications

a. Meter Indication: Reading the LIN-LOG presentation is quite easy. Merely read the pointer that is "on scale". The black pointer is read up to 50 mrem/h, above which it disappears from view and the red pointer is read. The fluctuation of the pointer is normal and is caused by the random nature of radioactive emissions. Watch the pointer long enough to obtain the average reading.

b. Phone: When using an earphone, a click will be heard for each event counted. Using an Eberline Model SK-1 speaker, only one-half the number counted will be heard.

3. Monitoring

Monitoring procedures depend greatly on the situation at hand. Therefore, no specifics will be given. The detector may be used attached or removed from the instrument. If a different length cable is used, the high voltage may have to be readjusted; refer to Section IV.C.

4. Stopping

To shut down the instrument, merely move the switch to the *OFF* position.

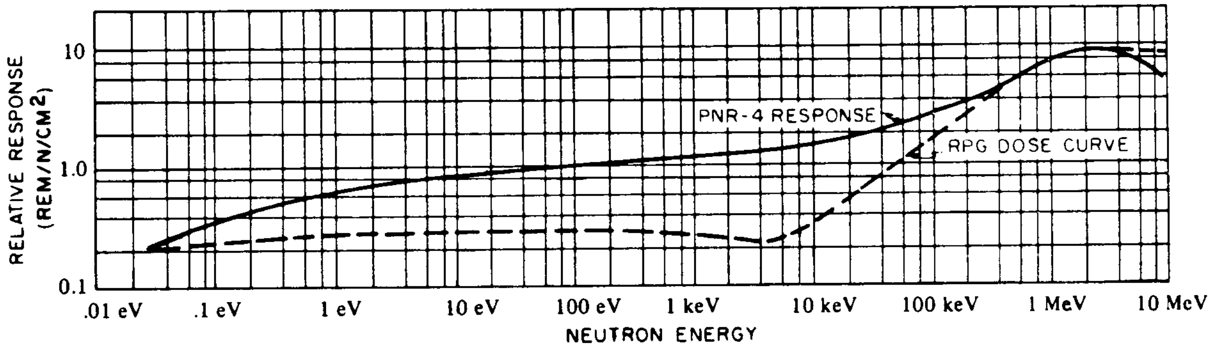


Figure 2-1. Neutron Energy Response Curve

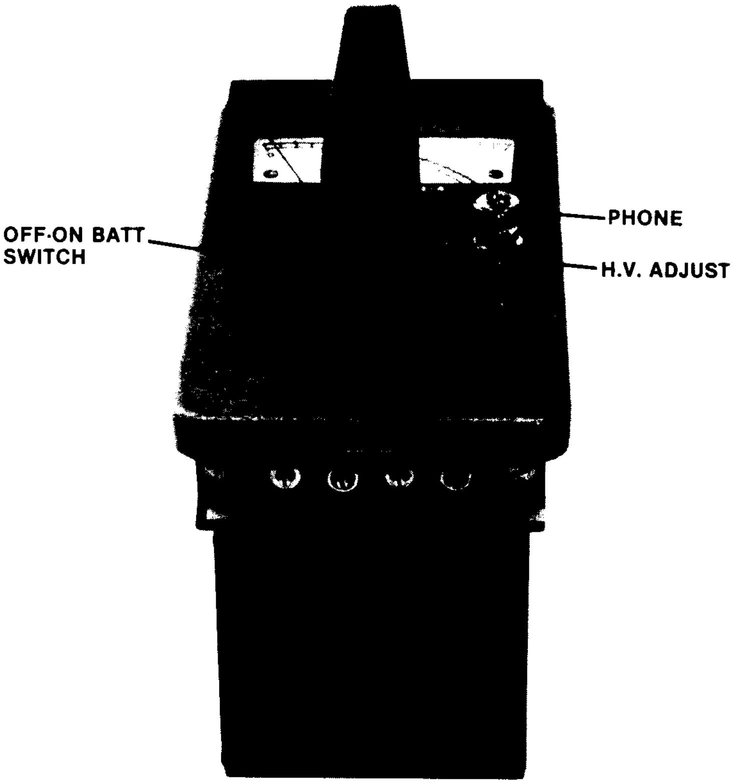


Figure 2-2. Model PNR-4 Exterior Controls

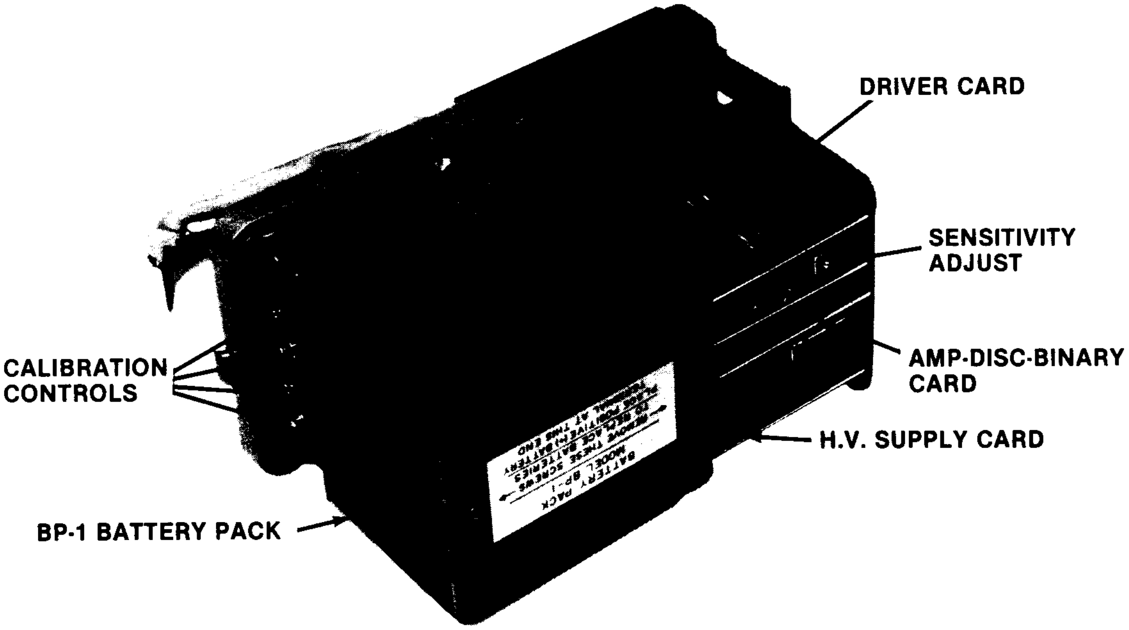


Figure 2-3. Model PNR-4 Interior Controls

SECTION III
THEORY OF OPERATION

A. GENERAL (See Figure 3-1)

The detector, when in a radioactive field, generates electrical pulses. These pulses are coupled into an amplifier, and after amplification they are applied to a pulse-height discriminator. If they are of sufficient amplitude, they cause the binary to change states. The square-wave output of the binary is applied to the driver. This converts the square-wave frequency into a proportional dc current which deflects the meters. Thus, the meter reading is proportional to the intensity of the radioactive field at the detector.

B. FUNCTIONAL THEORY

1. Detector

The detector tube itself is sensitive to slow neutrons. The matching of the energy response of the detector to the theoretical dose curve is a delicate balance of capturing some slow neutrons vs moderating and capturing fewer fast neutrons. For complete theory and data refer to the reference material (footnotes on page 1).

When the B^{10} atom inside the tube captures a neutron, it releases an alpha particle. The energy released ionizes the gas in the tube. The negative ions are accelerated to the anode wire because of the positive high voltage applied. As they approach the wire they have sufficient energy to ionize more atoms, causing ion amplification. The amount of amplification is controlled by the high voltage. The amplified current pulse is coupled through the cable into the instrument, then to the amplifier.

2. Amplifier-Discriminator-Binary
(See Figures 2-3, 6-1, 6-3)

a. Amplifier: The amplifier portion of this card consists of Q201 through Q205 and associated circuitry. Q201 and Q202 form a differential amplifier input. Q203 and Q204 are direct-coupled gain stages. Q205 is basically an emitter follower with a feedback signal taken from the emitter. The amount of feedback applied to Q202 base is controlled by the ratio of resistances of R207 and R205. The higher the resistance of R207, the more feedback there is, thereby decreasing the gain.

b. Discriminator: The collector of Q205 is a current source which drives tunnel diode CR202. When the current, due to a pulse, exceeds the diode peak current, it switches to its high voltage state. When it switches, it saturates Q206, causing a sharp decrease in its collector voltage. After the pulse, CR202 switches back to its low voltage state, Q206 is turned off, and its collector is free to rise back to positive voltage.

c. Binary: The two stable states of the binary are as follows:

(1) Q207 and Q210 *ON*, Q208 and Q209 *OFF*, resulting in output H at 0 V and output J at positive supply voltage.

(2) Q208 and Q209 *ON*, Q207 and Q210 *OFF*, resulting in output H at positive supply voltage and output J at 0 V.

These two states are entirely symmetrical, and the PNR-4 holds in either state due to cross connections from outputs to opposite bases. Switching from one state to the other occurs when Q206 saturates. This signal is coupled through the forward-biased diode (CR203 or CR204), and through the corresponding capacitor (C203 or C204) into the base of the *ON* transistor (Q207 or Q208). This turns that transistor *OFF* and its corresponding rise in collector voltage is coupled to the other side to switch the binary.

Thus, the two outputs (pins H and J) are alternately at positive supply voltage and ground, switching states for each pulse that exceeds the discrimination level.

3. Driver (P-203) (See Figures 2-3, 6-1, 6-2)

The driver card contains four similar sections (one for each decade of frequency response), which convert the signal from the binary into a dc current which is proportional to the frequency of the input. The pair of input capacitors (C301 and C302 for section 1, etc.) determine the frequency response for each section. These capacitors are different by a factor of 10 in each section, causing the same difference in the frequency response.

The capacitors on the output collector of each section (C303, etc.) slow the meter response time to aid in averaging the meter reading.

4. Calibration

Section 1 and 2 of the driver combine to deflect meter one, and sections 3 and 4 to deflect meter two. The calibration controls adjust this combination for the proper meter reading vs input count rate. Each pair of sections and meter is completely independent of the other.

The first control (R2 and R4 respectively) adjusts the slope of the meter current vs frequency line for both sections. The second control (R3 and R5 respectively) adjusts the point where the lower frequency section saturates. This saturation forms a stable base upon which the higher frequency section operates.

5. High Voltage Power Supply (P201-B)

(See Figures 2-3, 6-1, 6-4)

The P-201B high-voltage power supply replaces the P-201A, P-201A-XXX, and the P-201AS in new Eberline instruments. It is a direct plug-in replacement for the older "A" versions in all Eberline instruments. The P-201B develops 300 to 2500 V for detector operation.

The P-201B consists of a controlled blocking oscillator, Q1; voltage set-up and rectification, T1, C1-C5, and CR1-CR5; high-voltage division, R11; feedback buffer and error amplifier, A1; and oscillator level control, Q2.

The regulation circuit is in balance when the feedback voltage from R11 is equal to the reference voltage on A1, pin 5. This is equal to one-half the *V ADJ* input and is 1/1000 of the high voltage output. Increasing the *V ADJ* input unbalances the differential amplifier, which increases the level of the oscillator and the high-voltage output. R11 then feeds back a greater voltage, rebalancing the circuit at the higher reference and high voltage output.

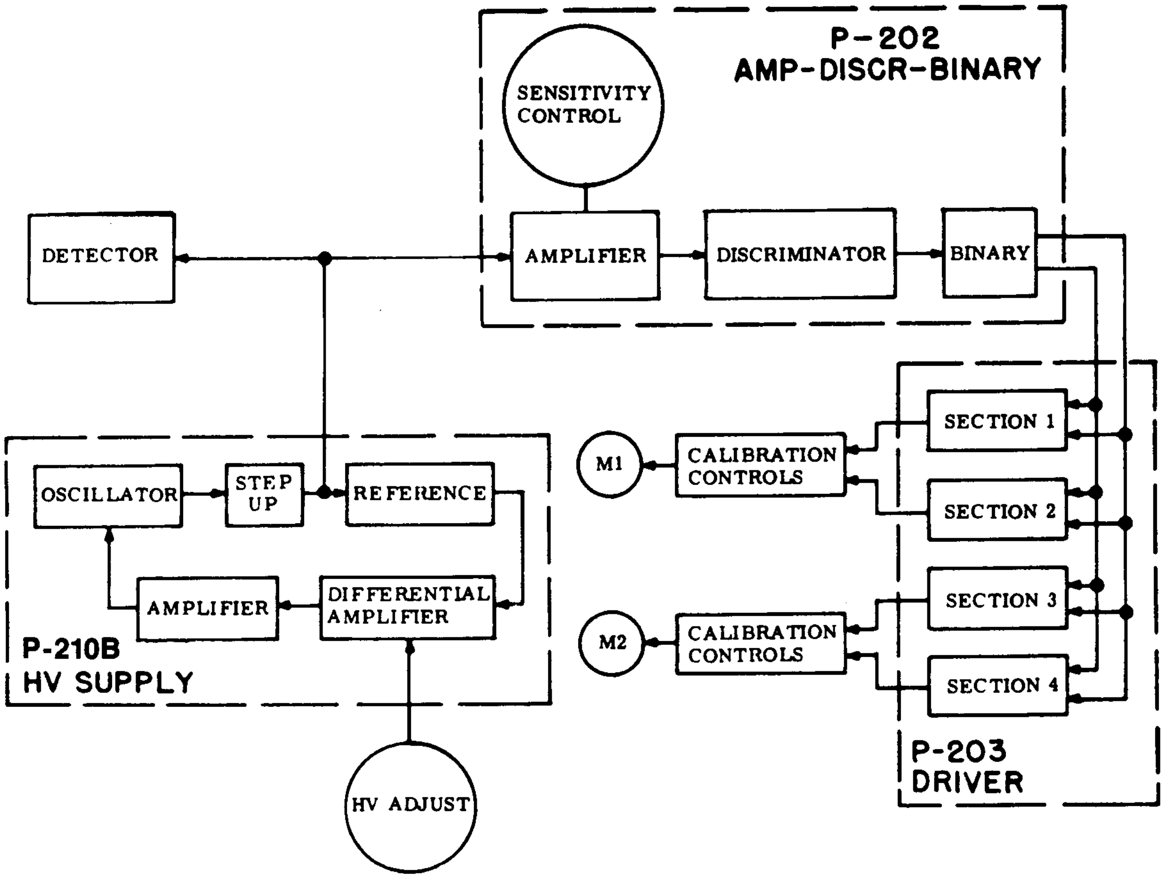


Figure 3-1. System Block Diagram

SECTION IV
MAINTENANCE

A. DISASSEMBLY AND REASSEMBLY

1. Detector

To remove the detector assembly from the instrument, disconnect the detector end of the cable and depress the button at the rear of the mount under the can. The two units will then separate. The tube may be removed by taking out the chrome-plated retaining nut and then pulling the tube from the sphere. The sphere may be disassembled by loosening and removing the metal band.

Handle the small inner sphere with care or the thin cadmium layer may be damaged.

2. Electronic Chassis

Remove the chassis from the case by releasing the spring-loaded catches at each end.

a. Batteries (BP-1 Pack): Batteries may be replaced with the pack left in the instrument by removing the two surface screws. The entire pack may be removed by removing the two recessed screws. Reassemble in reverse order of disassembly, being certain to observe battery polarity.

b. Electronic Modules: Any of the three modules may be removed by removing its retaining screw, then pulling out the module. When replacing, align the card with the socket, push it in and replace the screw.

B. PREVENTIVE MAINTENANCE

The instrument is splashproof; however, it should be kept as clean and dry as possible.

Change the batteries when their check reading falls below the "BATT" area on the meter. Never leave batteries in the instrument if it is to be inactive for a long period of time.

C. CALIBRATION

To set up and calibrate the instrument three separate steps are required: (1) sensitivity adjustment, (2) calibration, and (3) high voltage adjustment.

1. Sensitivity Adjustment (See Figure 2-3)

This adjustment is not critical since the high voltage will compensate for a wide range of settings. However, if set too sensitive, the instrument is susceptible to noise; if set too insensitive, linearity of the detector operation is affected. Optimum setting is about 2 mV, which can be approximated by two counterclockwise turns from extreme clockwise rotation.

2. Calibration

The PNR-4 may be calibrated directly to a neutron field if a calibrated neutron range is available. Before calibrating, the high voltage must be adjusted properly as outlined in Section IV.C.3.

To calibrate, follow the procedure below:

a. Turn R3 and R5 maximum clockwise.

b. Place the instrument in a 4 mrem/h field and adjust R2 for a 4 mrem/h reading.

c. Place the instrument in a 40 mrem/h field and adjust R3 for a 40 mrem/h reading.

d. Place the instrument in a 400 mrem/h field and adjust R4 for a 400 mrem/h reading.

e. Place the instrument in a 4k mrem/h field and adjust R5 for a 4k mrem/h reading.

If a calibrated neutron range is not available, calibration may be accomplished by using a pulse generator. The pulse generator must have a negative pulse of at least 3 mV amplitude with a rise time faster than 1 microsecond (μs) with frequency variable from below 200 ppm (pulses per minute) to 200k ppm.

Remove the instrument from its case and remove the high voltage supply from the instrument. Connect the pulse generator to the spring connector (junction of R8 and C2).

Follow the same procedure as above except adjust pulse generator frequency to correspond to the count rate from each field (200 ppm is equal to 4 mrem/h).

After pulser calibration, make sure that the instrument is sensitive to neutrons.

3. High Voltage Adjustment (See Figure 2-2)

The proper setting for the high voltage is to operate on the flat portion of the plateau below the gamma threshold. One method of arriving at this setting is to turn up the voltage slowly with the detector in a gamma field until counting is observed. This will be the gamma threshold. Turn the voltage down until this counting stops.

A preferable method is to run a plateau with the detector in a neutron field, and a second plateau with the detector in a gamma field equal to the intensity of gamma it is desired to reject. From the two curves, select the optimum setting for the high voltage. Refer to Figure 4-1 for a typical plateau.

A longer cable between the detector and counter will cause the plateau to be shifted to higher voltages because of capacitive loading effect. Therefore, the instrument should be set up with the cable with which it is to be used.

NOTE

An electrostatic voltmeter (or other voltmeter with 1000 MΩ minimum input impedance) should be used to measure the high voltage to prevent loading. Connect to contact A (front contact) of the high voltage supply card.

D. TROUBLESHOOTING

The best method for troubleshooting the instrument is by substitution of modules. Replace the detector, cable, high voltage supply, amplifier-discriminator-binary and driver card systematically to isolate the trouble. If this does not locate the trouble, the chassis assembly is at fault. Check the zener diode voltage (CR-1). If this is proper, separate the chassis and cover and visually inspect for shorts or opens. If a module is found to be faulty, troubleshoot by referring to Figure 6-1; or it may be returned to Eberline for repair.

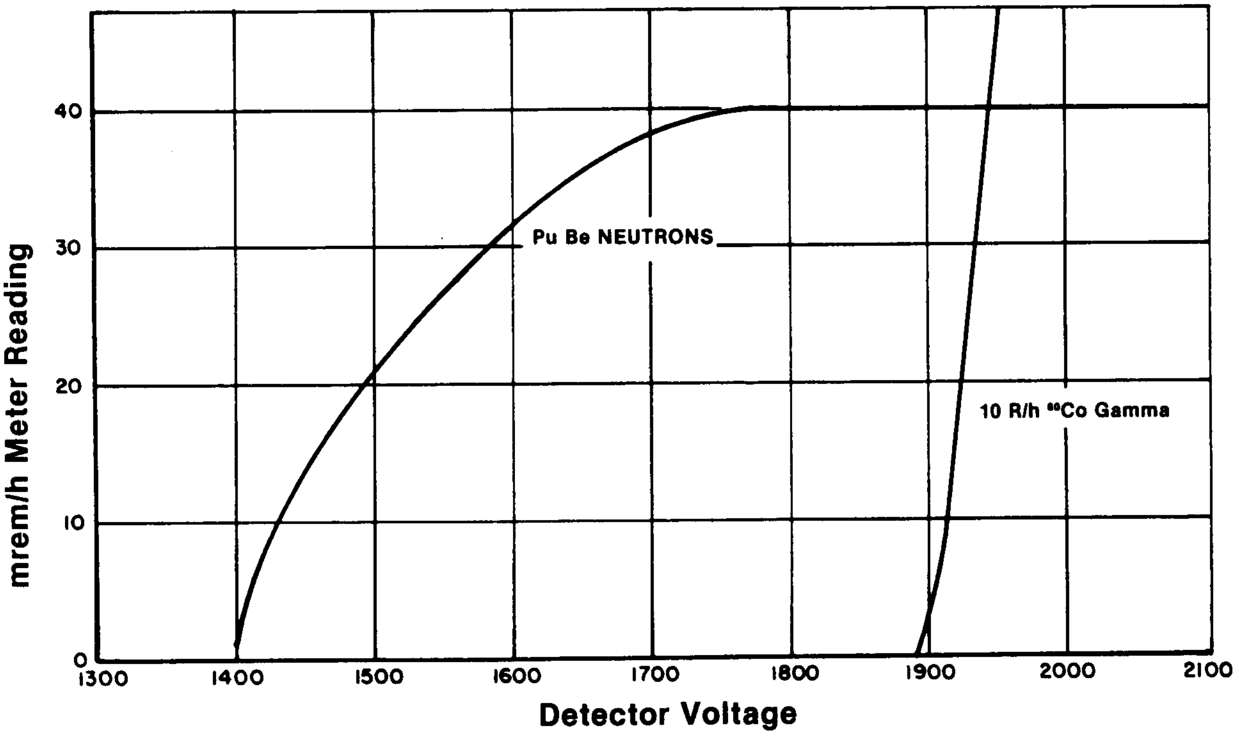


Figure 4-1. Typical High Voltage Plateau Curve for PNR-4 Detector

SECTION V
PARTS LIST

The following table lists the electronic items incorporated in the PNR-4 and should contain any part necessary for normal electronic repair. Unless otherwise specified, callouts of manufacturers and manufacturers' part numbers are to be considered typical examples only. There are no restrictions against using equivalent parts with the same operating characteristics. When ordering parts from Eberline, specify model number, serial number, reference designation, value, Eberline part number, or a word description if the part has no reference designation. Eberline will automatically substitute equivalent parts when the one called out by the manufacturers' part number is not available.

REF DESIG	PART	DESCRIPTION	MANUFACTURER AND PART NUMBER	EBERLINE PART NUMBER
1. Cover Assembly YP10416000 (4)				
J3	Connector, Audio	BNC	31-102 Amphenol or UG-657U	CXBN7 (4)
M1	Meter	0-50 μA	Eberline 10416-B01 (Black)	MTPA25 (2)
M2	Meter	0-50 μA	Eberline 10416-B01 (Red)	MTPA26 (1)
R1	Potentiometer	25k	A-B GA2M028S253UW	PTCC253B03 (2)
S1	Switch		Eberline 10416-B05	SWRO26 (0)
2. Terminal Board TB1 2P10416013 (7)				
C1	Capacitor	120 μF, 10%, 10 V	CS13	CPTA121M3F (4)
C2	Capacitor	220 pF, 10%, 3 kV	Centralab DD30-221	CPCE221P3Y (5)
C3	Capacitor	0.01 μF, 20%, 3 kV	Sprague 30GA-S10	CPCE103P4Y (5)
CR1	Zener Diode	5.3 V	Eberline 10416-A24	CRXX1 (8)
R6	Resistor	100 ohm, 5%, 1/4 W		RECC101B22 (6)
R7	Resistor	180k, 5%, 1/4 W		RECC184B22 (2)
R8	Resistor	390k, 5%, 1/4 W		RECC394B22 (7)
R9	Resistor	4.7k, 5%, 1/4 W		RECC472B22 (1)
3. Chassis Assembly				
R2, R4	Potentiometer	10k, Linear Taper	RV6LAYSA103A	PTCC103B23 (5)
R3, R5	Potentiometer	250k, Linear Taper	RV6LAYSA254A	PTCC254B03 (0)
4. HV Supply, P201B				
A1	Integrated Circuit	Op-Amp	National LM324N	ICAOA0324N (6)
C1, C2, C3	Capacitor	0.0047 μF, 3 kV	Sprague 30GA-D47	CPXX13 (7)
C4, C5	Capacitor	0.01 μF, 3 kV	Sprague 30GA-S10	CPCE103P4Y (3)
C6	Capacitor	0.1 μF, 100 V	Erie type CK06BX104K	CPCE104P3P (5)

REF DESIG	PART	DESCRIPTION	MANUFACTURER AND PART NUMBER	EBERLINE PART NUMBER
4. HV Supply, P-201B (continued)				
C7	Capacitor	1000 pF, 100 V	Centralab CN20A102K	CPCE102P3P (9)
C8	Capacitor	220 μF, 10 V	Sprague 150D227X9010S2	CPTA221M3F (2)
C9	Capacitor	0.27 μF, 50 V	Sprague CW30C274XM	CPCE274P4N (6)
C10	Capacitor	0.002 μF, 1 kV	Centralab DD-202	CPCE202P4U (7)
CR1, CR2, CR3, CR4, CR5	Rectifier	Silicon, 2.5 kV	Varo VA25	CRSIVA0025 (3)
Q1	Transistor	PNP, Silicon	Motorola MJE371	TRSPMJE371 (1)
Q2	Transistor	NPN, Silicon	2N4124	TRSN2N4124 (2)
R1	Resistor	22 MΩ, 1/8 W, 5%	Carbon Composition	RECC226B21 (2)
R2	Resistor	1 MΩ, 1/8 W, 5%	Carbon Composition	RECC105B21 (8)
R3	Resistor	300 Ω, 1/4 W, 5%	Carbon Composition	RECC301B22 (2)
R4	Resistor	4.7k, 1/4 W, 5%	Carbon Composition	RECC472B22 (1)
R5	Resistor	10k, 1/4 W, 5%	Carbon Compostion	RECC103B22 (4)
R6	Resistor	100k, 1/4 W, 5%	Carbon Composition	RECC104B22 (0)
R7	Resistor	1k, 1/4 W, 5%	Carbon Composition	RECC102B22 (4)
R8	Resistor	150 kΩ, 1/4 W, 1%	RN55D	RECE154B12 (5)
R9	Resistor	100k, 1/4 W, 1%	RN55D	RECE104B12 (0)
R10	Resistor	1.0 MΩ, 1/4 W, 5%	Carbon Composition	RECC105B22 (7)
R11	Resistive Divider	1000M/1M	TRW/IRC type	REXX22 (4)
T1	Transformer	High Voltage	Microtran M8149	TFHV5 (3)
5. Amplifier-Discriminator-Binary, P-202				
C201	Capacitor	0.33 μF, 10%, 35 V	CS13	CPTA334P3L (2)
C202	Capacitor	100 pF, 10%, 100 V	ERIE CK12BX101M	CPCE101P3P (1)
C203, C204	Capacitor	220 pF, 10%, 100 V	ERIE CK12BX221K	CPCE221P3P (7)
C205, C206	Capacitor	2200 pF, 10%, 200 V	Sprague 192P22292	CPPF222P3R (1)
C207	Capacitor	120 μF, 10%, 10 V	CS13	CPTA121M3F (4)
CR201, CR203, CR204	Diode		1N4148	CRSI1N4148 (7)
CR202	Tunnel Diode		1N3712	CRTU1N3712 (6)
Q201, Q202, Q204, Q207, Q208	Transistor		2N4124	TRSN2N4124 (2)
Q203, Q205, Q209, Q210	Transistor		2N4126	TRSP2N4126 (8)
Q206	Transistor		2N1304	TRGN2N1304 (3)
R201, R202, R205	Resistor	100k, 5%, 1/4 W		RECC104B22 (0)

REF DESIG	PART	DESCRIPTION	MANUFACTURER AND PART NUMBER	EBERLINE PART NUMBER
5. Amplifier-Discriminator-Binary, P-202 (continued)				
R203, R204, R212, R213	Resistor	4.7k, 5%, 1/4 W		RECC472B22 (1)
R206	Resistor	150k, 5%, 1/4 W		RECC154B22 (5)
R208	Resistor	2.2k, 5%, 1/4 W		RECC222B22 (0)
R210	Resistor	2.7k, 5%, 1/4 W		RECC272B22 (5)
R209, R214, R215, R216, R217	Resistor	10k, 5%, 1/4 W		RECC103B22 (2)
R211	Resistor	22k, 5%, 1/4 W		RECC223B22 (8)
R218, R219	Resistor	8.2k, 5%, 1/4 W		RECC822B22 (7)
R220	Resistor	220 ohm, 5%, 1/4 W		RECC221B22 (2)
R207	Potentiometer	5k	Bournes 3005P-1-502	PTWW502B04 (5)
6. Driver Card, P-203-4				
C301, C302	Capacitor	2.2 μF, 10%, 20 V	CS13	CPTA225P3I (7)
C303, C306	Capacitor	120 μF, 10%, 10 V	CS13	CPTA121M3F (4)
C304, C305	Capacitor	0.22 μF, 10%, 35 V	CS13	CPTA224P3L (5)
C307, C308	Capacitor	0.022 μF, 10%, 200 V	Sprague 192P22392	CPPF223P3R (9)
C309	Capacitor	15 μF, 10%, 10 V	CS13	CPTA150M3F (3)
C310, C311	Capacitor	0.0022 μF, 10%, 200 V	Sprague 192P22292	CPPF222P3R (1)
C312	Capacitor	3.3 μF, 10%, 15 V	CS13	CPTA335P3H (5)
CR301-CR308	Diode		1N4148	CRSI1N4148 (7)
Q301, Q302, Q303, Q304, Q305, Q306, Q307, Q308	Transistor		2N4126	TRSP2N4126 (8)
R301, R302, R304, R305, R307, R308, R310, R311	Resistor	2.2k, 5%, 1/4 W		RECC222B22 (0)
R303, R306, R309, R312	Resistor	47k, 5%, 1/4 W		RECC473B22 (9)
7. Cable CA-12-60				
	Connector	MHV Plug		CXMH6 (8)
	Cable	Coaxial Cable	RG-62B/U	WRCX3 (6)
	O-ring	Silicone	2-113	ORSI2113 (2)
8. Neutron Ball NRD				
	Detector	Neutron, BF3	Nancy Wood G-5-1	TUGM18 (8)
	Handle	Plastic		HDHA5 (4)

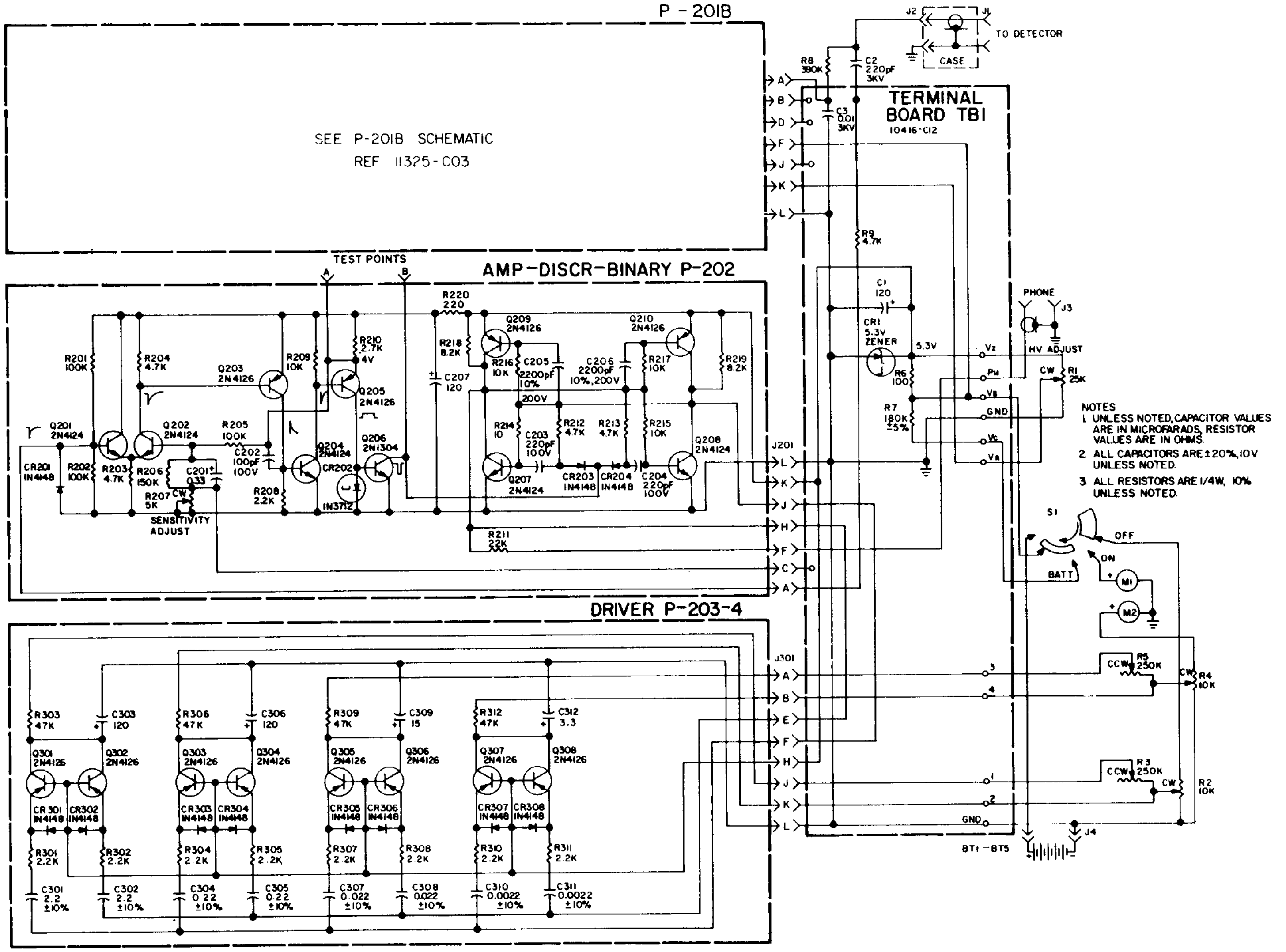


Figure 6-1. General Schematic of Model PNR-4 (10478-C190)

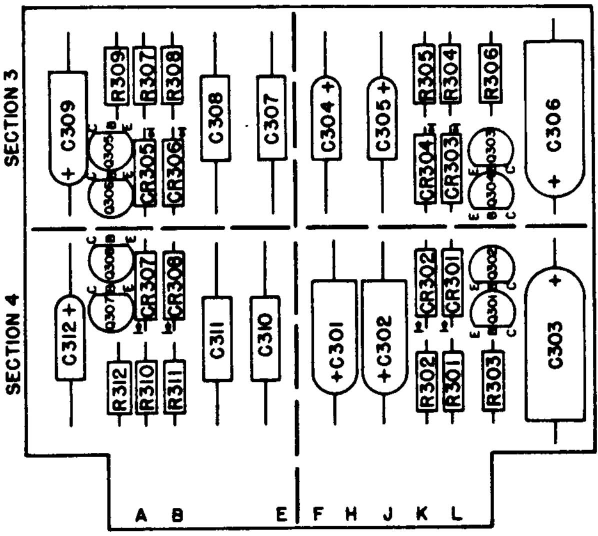


Figure 6-2. Component Layout of Driver Card P-203-4

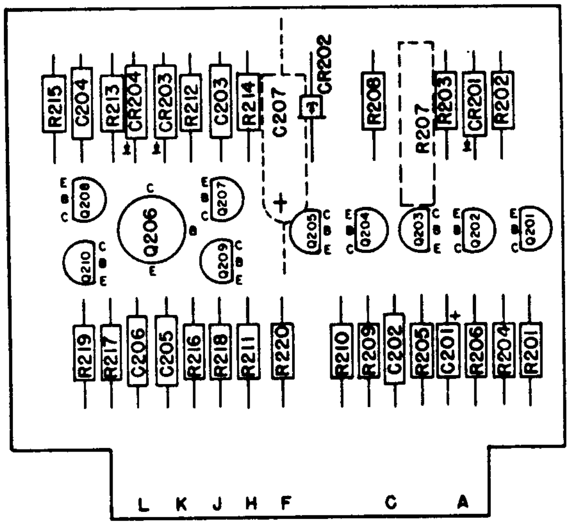
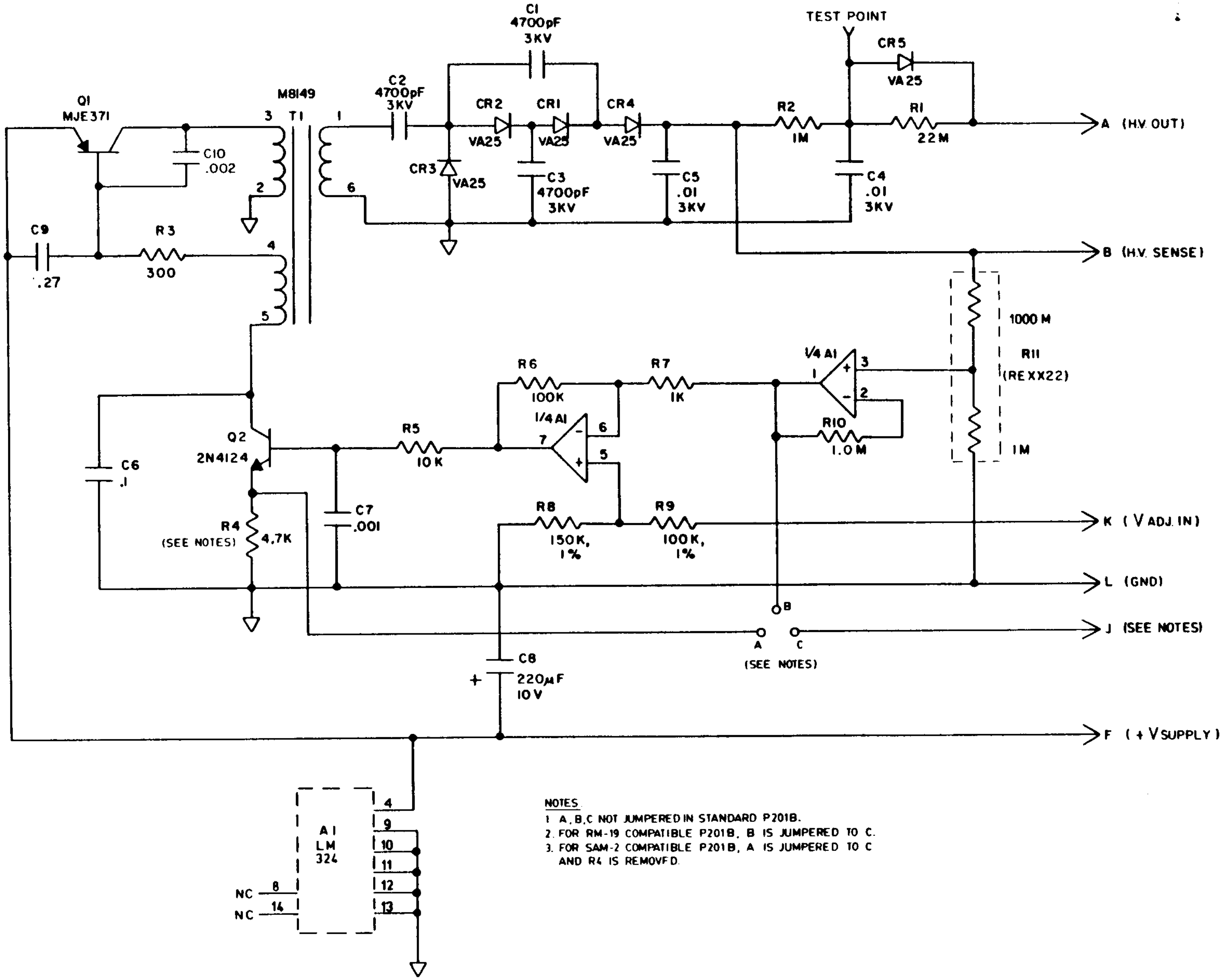


Figure 6-3. Component Layout of Amplifier-Discriminator-Binary Card P-202



NOTES

1. A, B, C NOT JUMPERED IN STANDARD P201B.
2. FOR RM-19 COMPATIBLE P201B, B IS JUMPERED TO C.
3. FOR SAM-2 COMPATIBLE P201B, A IS JUMPERED TO C AND R4 IS REMOVED.

Figure 6-4. P-201B Schematic, 11325-C03E

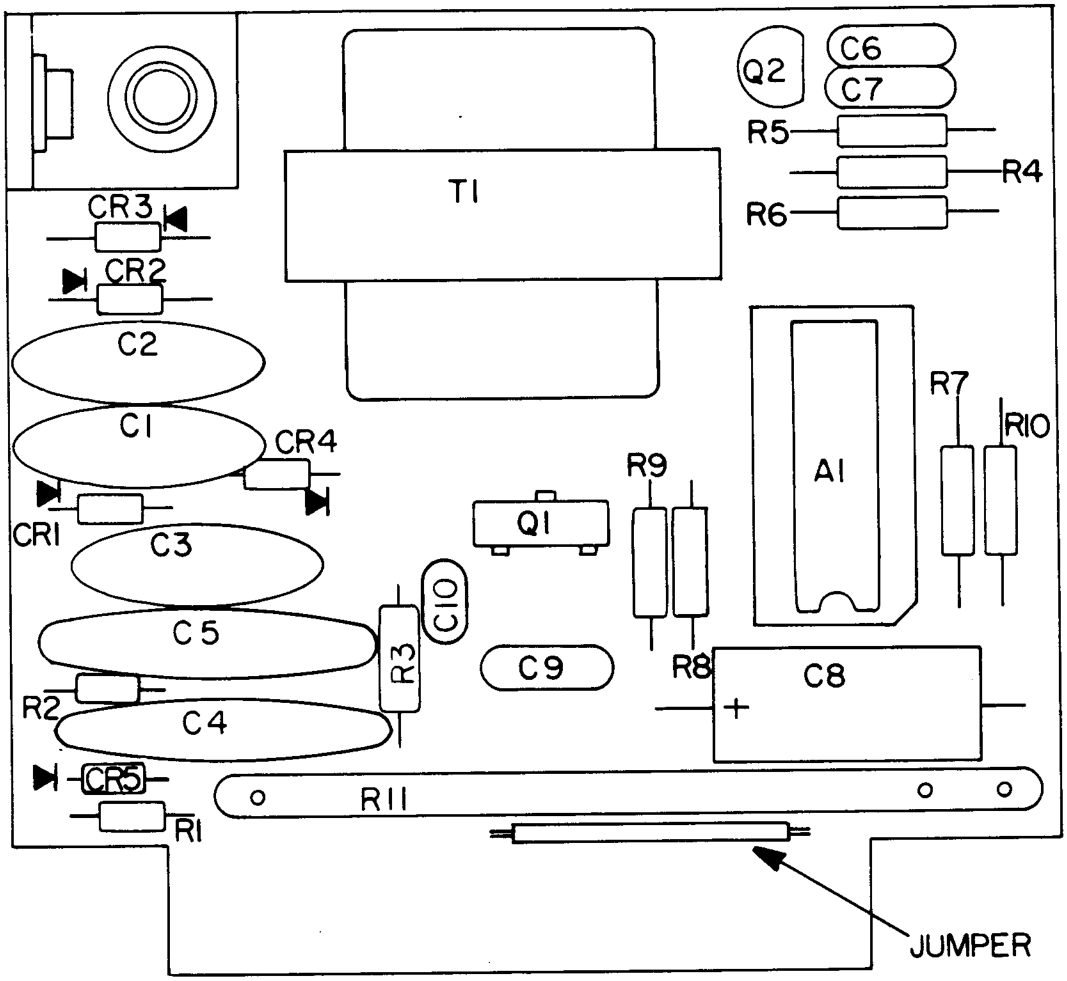


Figure 6-5. P-201B Component Assembly, 11325-C06A